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14. ABSTRACT
This TOP provides guidance for conducting sand and dust tests using an outdoor test facility. Outdoor facilities are required when a chamber test is not feasible due to test article size and/or chamber size limitations. Two procedures are described. One approximates the sand test guidance outlined in Military Standard (MIL-STD)-810G. The second method is offered as an alternative and attempts to meet both sand and dust test requirements in one test; i.e., sand and dust are mixed at concentrations approximating MIL-STD-810 test levels. This document describes some of the instrumentation, test equipment, and data collection and processing procedures.

15. SUBJECT TERMS

Sand Test	Environmental Test	Particle Size Distribution
Dust Test	Climatic Testing	MIL-STD-810

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

Test Operations Procedure (TOP) 1-2-621 6 February 2009
DTIC AD No.

OUTDOOR SAND AND DUST TESTING

1. SCOPE.

a. This TOP provides guidance procedures to conduct sand and dust tests on military materiel using an outdoor test facility. Outdoor facilities are required when a chamber test is not feasible due to chamber size limitations. Two procedures are described. One approximates the sand test guidance outlined in Military Standard (MIL-STD)-810G[1*]. The second method is offered as an alternative and attempts to meet both sand and dust test requirements in one test; i.e., sand and dust are mixed at concentrations approximating MIL-STD-810 test levels. This document describes the instrumentation, test equipment, and data collection and processing procedures.

b. Limitations.

(1) Temperature. MIL-STD-810 sand/dust procedures require the unit under test (UUT) to be tested at the high operating or storage temperature (~ 60 - 71˚C). Most Army test chambers are limited in size and thus sand/dust testing of large test items may not be possible. This TOP provides an alternative test method which recommends testing at ambient temperature conditions.

(2) Weather. Weather conditions need to be monitored as temperature, relative humidity, and ambient wind conditions affect test equipment performance. This TOP describes test methods that are performed outdoors under the prevailing weather conditions and thus testing is limited to calm, dry days [recommend winds less than 4.5 m/s (10 mph) with occasional gusts up to 7 m/s (15 mph) and relative humidity (RH) less than 30%].

(3) Particle Size and Granularity. This method recommends utilizing sand material that is supplied by local businesses (playground sand). This sand material must be characterized before test conduct to determine if the product meets the customer's objective (i.e., sand particle size distribution in the UUT's anticipated deployment location). Use sand of sub-angular structure, a mean Krumbein number range of 0.5 to 0.7 for both roundness and sphericity and a hardness factor of 7 mohs (see Appendix B). The media may be tailored by adding "designer" dust but the result may not exactly match the particle size and granularity requirements of MIL-STD-810.

(4) Dust Concentration. The dust concentration values in the combined sand/dust method of this TOP may be lower than the MIL-STD-810 requirement of 3 to 17 g/m^3. Test equipment limitations, test item size, and outdoor weather conditions may significantly alter the amount of material impacting the UUT.

(5) Wind Speed. MIL-STD-810 specifies a wind speed of 18 m/s (40 mph) for sand and 9 m/s (20 mph) for dust testing. The combined sand/dust test described in this method is conducted at 18 m/s (40 mph); therefore, test results may differ from those observed in the conventional chamber test. Wind gusts or higher speeds may be added if required by the life cycle environmental profile. The MIL-STD-810 dust procedure is performed to ascertain the ability of equipment to resist the effects of dust particles which may penetrate into cracks, crevices, and joints (e.g., the caking of dust at openings). Combining the blowing dust with

[*] Superscript numbers and letters correspond to those found in Appendix C, References.

blowing sand is recommended when the objective is to detect material penetrations. The higher wind speed will increase the likelihood of dust penetration, but clogging and caking issues might not occur for certain test articles.

(6) Exposure Time. This TOP recommends an exposure duration of 90 minutes per face. The MIL-STD-810 dust test specifies the exposure time to be 6 hours at ambient temperature and 6 hours at high temperature (i.e., 12 exposures for a 6 sided item which is 90 minutes per face per temperature). The combined sand/dust method test time is limited to the MIL-STD-810 sand test value (90 minutes per face) due to the concentration of sand employed in the test. Shorter time periods (e.g.; 30 minutes per side) may be acceptable if the only test objective is to determine sand/dust intrusion through seals, etc, during non-operational UUT scenarios.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Outdoor Test Area	Selected to provide adequate protection for personnel and equipment and to facilitate emplacement of the test articles and wind machine and sand/dust injection system. Figures 1 and 2 show typical test facilities and equipment.
Wind Generation Machine	To be able to provide wind speeds up to 18 m/s (40 mph) over a broad area. Two or more machines may be necessary for extremely large test items. [The149 KW (200 HP) wind machine in Figure 1 produces 18 m/s (40 mph) winds at 6 m (20 feet). The airboat design of Figure 2 produce 316 KW (425 HP) and wind speeds up to 45 m/s (100 mph).] Note, an axial propeller fan will cause rotational swirl in the fan outlet airflow and a centrifugal fan will create a gradient in the airflow across the fan exit plane. In either case, a flow straightener is recommended at the fan exit to create a more uniform airflow at the test item.
Sand and Dust Injection System (see Figure 1)	System must be capable of dispersing the sand/dust media uniformly across the face of the UUT at the desired flow rates/volumes.
Air Flow Straightener (see Figure 2)	An air flow straightener will improve test bed resistance to ambient side/crosswinds which can disrupt direction of intended sand particle impact target. The straightener can be simply constructed from telephone poles dropped into metallic welded U-channel end pieces.

2.2 Instrumentation.

Devices for Measuring	Measurement Uncertainty (2σ)
Wind Speed	± 2 m/s
Sand/Dust Characteristics (particle size, roundness, etc)	As required
Sand/Dust Concentrations (weight)	As required
Time	±1 second
Meteorological Conditions	As required

Figure 1. Typical Sand and Dust Injection System with 200 HP Wind Generator in Background

Figure 2. Typical Air Flow Straightener with 245 HP Wind Generator

2.3 Equipment Calibration.

a. All test equipment shall be calibrated in accordance with International Standards Organization (ISO) 10012-1[2] with calibration traceable to the National Institute of Standards and Technology. All calibration records shall be maintained on file and made available for inspection as required.

b. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified prior to and following each test then calibrated in pre-determined intervals and shall meet the requirements of ISO 10012-1 to the satisfaction of the procuring activity.

3. REQUIRED TEST CONDITIONS.

3.1 Test Objectives and Approach.

The UUT (missiles, rockets, launchers, ground support vehicles, unmanned aerial vehicles, etc.) is usually subjected to the various environmental tests defined in the system Life Cycle Environmental Profile. The blowing sand and blowing dust tests are often performed as two distinct tests near the end of the climatic test sequence. These tests can easily be conducted on small items in standard test chambers. For large test items, a different test method is required due to the unavailability of large sand/dust test chambers. The tests outlined below provide an alternative which roughly approximates the damage effects of the MIL-STD-810 sand and dust test methods.

3.2 Test Requirements.

a. Operating Versus Storage Configuration. Determine if the UUT needs to be tested in the storage or operational configuration. For those items requiring operation, determine the point at which operational testing is to begin. Usually operational testing takes place at some point within the last hour of the surface exposure that is most vulnerable. Operational time should be at least ten minutes.

b. Special Test Preparations. Because of the abrasive nature of the sand and dust, the tester may consider using a protective barrier on components of the UUT that knowingly will be damaged by test. For example, when testing an operations control shelter mounted on a HMMWV, protect the vehicle’s glass items such as windows and mirrors.

c. Test Item Temperature Conditioning. MIL-STD-810 requires temperature conditioning of the UUT at the hot operating temperature. The outdoor test scenario does not easily lend itself to temperature conditioning. Temperature conditioning can be achieved with a portable temperature shroud/conditioning unit or with a large temperature chamber near the outdoor test area. The conditioning environment will have to be removed before sand and/or dust exposure is initiated and the UUT temperature will decay to ambient conditions well before the end of the first exposure. While temperature conditioning is possible, the extra effort (schedule and man-hour costs) to create this environment isn’t necessary for most UUT. Review UUT specifications to determine whether temperature will be a factor in performance.

3.3 Meteorological Conditions.

This test is performed outdoors and is influenced by uncontrolled conditions. The test shall be postponed in the event of extreme weather. Relative humidity levels shall not exceed 30 %. Ambient winds shall not exceed 4.5 m/s (10 mph) with occasional gusts up to 7 m/s (15 mph). If the (cross) winds are too high, the sand/dust plume will be diverted and much of the material will not impact the UUT. High humidity greatly affects sand and dust exposure levels. The dust particles will be heavier and fall to the ground before impacting the UUT and result in an unequal cross-sectional area distribution pattern (i.e., “hot” or “null” spots could occur). Testing in higher humidity conditions may be performed if extra steps are made to ensure a dry media.

3.4 Test Item Failure.

The following conditions constitute a test item failure.

a. Non-fulfillment of safety requirements or the development of safety hazards.

b. Sand and dust penetration causes binding, clogging or seizure of moving parts.

c. Excessive abrasion or erosion of material coatings.

d. Sand abrasion and dust accumulation prevents successful functional tests.

3.5 Safety Requirements.

a. Follow the local Safety Standing Operating Procedure (SSOP) when conducting operations with explosive components. An example may be found in ATC SOP 385-2386[a]. Personnel involved in test operations shall be thoroughly aware of the hazards and take appropriate precautions to conduct operations in a safe manner.

b. Sand and dust mixtures may contain carcinogens or be otherwise hazardous to human health. Refer to the supplier's Material Safety Data Sheet (MSDS) or equivalent for health hazard data; e.g., exposure to silica can cause silicosis; other material may cause adverse health effects. Utilize the appropriate personal protection equipment such as masks, full face shields, hazardous material suit, etc.

c. The relatively dry test environment combined with the moving air and organic dust particles may cause a buildup of electrostatic energy that could affect operation of the test item. Use caution when making contact with the test item during or following testing if organic dust is used, and be aware of potential anomalies caused by electrostatic discharge during test item checkout.

d. For tests in which temperature conditioning is interrupted because of work schedules, etc., maintaining the test item at the test temperature for the time required will facilitate completion of the test when resumed. If the temperature is changed, before continuing the test, re-stabilize the test item at the temperature of the last successfully completed period before the interruption. **Caution: When soaking at high temperature, e.g., overnight, ensure the total test time at the most severe temperature does not exceed the life expectancy of any material.**

4. TEST PROCEDURES.

4.1 General.

a. The primary objective of this test is to ensure test item performance is within system specification; i.e., successfully withstands the exposure to a sand and dust environment. Some systems specify particle concentration levels targeted to meet system deployment areas. Others will specify the values of MIL-STD-810 which are as follows:

(1) Blowing Sand. For systems likely to be used close to helicopters operating over unpaved surfaces, use 2.2 ± 0.5 g/m^3 (0.06 ± 0.015 g/ft^3). For systems never used or exposed in the vicinity of operating aircraft, but which may be used or stored unprotected near operating surface vehicles, use 1.1 ± 0.3 g/m^3 (0.033 ± 0.0075 g/ft^3). For systems that will be subjected only to natural conditions, use 0.18 g/m^3 -0.0/+0.2 g/m^3 (0.005g/ft^3).

(2) Blowing Dust. The dust concentration is 10.6 ± 7 g/m^3 (0.3 ± 0.2 g/ft^3) unless otherwise specified. This concentration exceeds that normally associated with moving vehicles, aircraft, and troop movement, but has historically proven to be a reliable concentration for blowing dust tests.

For the combined sand and dust test procedure, dust concentration levels may need to be reduced due to equipment limitations. Certain screw type auger designs cannot pick up all of the fine particle dust to feed the injection system (i.e., there may not be enough large particles in the mixture to carry the dust forward through the pipe). Additionally, blowing wind speed differences (sand is double the speed of dust - see paragraph 1.b(5)) affects the particle impact velocity and particle impact distribution across the face of the UUT. Lastly, extra personnel safety precautions shall be taken on account of the large quantity of dust.

b. Determine the sand and dust particle size distribution and concentrations required to meet the test specification. Appendix A provides a brief comparison of the various mixtures utilized in previous tests at White Sands Missile Range. The sand/dust particle size may be characterized using the method outlined in Appendix B.

4.2 Test Conduct.

a. Sand Test. Visually inspect, photographically document, and functionally test the UUT prior to starting the exposure. The test article shall be subjected to blowing sand conditions for a total of 360 minutes (90 minutes per side) at an air velocity of 18 m/s (40 mph), with the most vulnerable side of the test article exposed last. Conduct the test as follows:

(1) Record ambient weather conditions. Ensure ambient wind speeds are below 4.5 m/s (10 mph) with occasional gusts up to 7 m/s (15 mph) and relative humidity is under 30%. If humidity is higher, ensure the sand material is relatively dry (e.g., bake it before test) in order to avoid caking in the sand injection system. Reschedule the test if conditions are not acceptable.

(2) Adjust the sand injection system to the required sand concentration level. This is normally done by operating the system for a short duration (one minute), collecting the material output and weighing it. Parameters for two different test configurations are shown in Appendix A, Table A-2.

(3) Validate the air speed with a hotwire anemometer or equivalent device at the location where the UUT is to be placed. The UUT is usually setup at a distance of 3 to 4 m (10-15 ft) from the wind machine outlet. This helps to provide better sand distribution across the face of the UUT and ensures that the sand particles have reached their terminal velocity. Perform a full system test run to verify the injection system is working properly; i.e., sand is being equally distributed across the test area.

(4) Place the first face of the UUT at the selected distance from the wind machine. If required, instrument the UUT with thermocouples and record temperatures for the duration of the test. Ground the UUT to avoid the buildup of electrostatic charge. (Disregard grounding if static electricity discharge effects are data points of user concern in final fielding and take careful attention, after test exposure, to closely monitor and record post test discharge effects that occur when test item is first handled for functional checks. This may include: loss of cryptographic variables, loss of configuration settings to serial/parallel data communications ports, etc. Evaluations of these effects should include user consideration aspects for potentials of causing mission critical failures in performance.)

(5) Start the wind machine, then the sand injection system and maintain conditions for 90 minutes.

(6) After the completion of 90 minutes of exposure, stop the sand injection system and wind machine.

(7) Rotate the UUT so as to expose the second face to the environment.

(8) Repeat steps (5) through (7) until all faces or other points of interest have been exposed to the environment.

(9) If operational checks are required, operate the UUT during the last 10 minutes of the last exposure to the environment. Otherwise, operational checks and visual inspections are performed at the end of the exposure. Ensure personnel operating the UUT are wearing the proper personal protection equipment when in direct exposure to the sand/dust environment.

(10) Record still photo or video images of the test setup, operations, and results as required. Figures 3, 4, and 5 show example test configurations. If required, collect, quantify, and characterize particle size and amount of sand that penetrates the UUT. This may be accomplished by thoroughly sweeping or vacuuming the interior spaces to collect the material and characterizing as described in Appendix B.

b. Sand and Dust Test. Conduct this test following the procedure outlined above (paragraph 4.2.a) but substituting a mixture of sand and dust. The dust is pre-mixed with the sand in a separate mixer at the required concentrations. See Appendix A, Table A-2 for example parameter configurations.

Figure 3. Typical Outdoor Sand and Dust Test

Figure 4. Typical Side View Wind Generator Field Test

Figure 5. Typical Front View Wind Generator Field Test

c. Temperature Conditioning. If temperature conditioning of the test article is required, verify operation of the chamber and the temperature data acquisition equipment. Place the UUT inside the climatic chamber. Install the necessary temperature measuring devices (thermocouples) on the test item and in the chamber. Start temperature conditioning by raising the temperature to the high temperature limit within the required period of time, i.e., at the specified temperature rate of change. Hold the chamber temperature until stabilization occurs. Stabilization has occurred when the slowest responding thermocouple of the test item is within 3ºC (5ºF) of the specified temperature. Once stabilized, quickly remove the UUT from the chamber, emplace in the test area, and begin the sand/dust test as described above. If portable conditioning units are employed at the test area, then remove the conditioning units and start the sand/dust test described above. Repeat the above process for each face of the test item.

5. DATA REQUIRED.

a. Test item S/N, date, and test item configuration.

b. Test equipment descriptions.

c. Instrumentation locations.

d. Results of pre/post test visual inspections, in particular sand and dust ingress.

e. Meteorological conditions (air temperature, RH, wind speed and direction)

f. Sand and dust particle size distribution and concentration.

g. Applied wind velocity, item orientation, test item temperature versus time, and exposure duration for each exposure/face.

h. Test record of significant observations and anomalies to include descriptions of any failures in the test item or test equipment.

i. Documentary photographs/video of the test/test setups.

j. Test item inspection and performance test results.

6. PRESENTATION OF DATA.

Test data may be presented in the form of plots, checklists, or tables similar to those shown in Appendix B.

APPENDIX A. BACKGROUND

1. The operation of vehicles in sand and dust environments can result in serious erosion damage to engine parts. Engine power loss, surge margin loss, and specific fuel consumption (or fuel usage) gain may adversely affect system safety. Sand and dust particles are highly abrasive and tend to erode the thin metal tips and trailing edges of gas turbine engine compressor blades and vanes. Coarse sand produces blade erosion and a near term loss of compressor efficiency. Fine sand causes plugging of cooling holes, deposits, and long term engine distress. Fine sand tests should be conducted to determine the engine's vulnerability to air hole plugging and the nature of deposits. Sand has been determined to be more detrimental during foreign operations due to the differences found in the sand composition. A lower melting point has been observed in foreign sand test samples which allow the sand to melt and form a glaze coating on the turbine airfoils. Spalling of the coating and base metal then occurs. Further information may be found in NASA TM 2008-215161[b] and USAAVLABS Technical Report 70-36[c].

2. Deposits formed in the test item depend upon the composition of the sand and dust. MIL-STD-810G states that "Silica flour, although not truly representative of dust found in the natural environment (except for particle size), has been widely used in dust testing and contains 97 to 99 percent (by weight) silicon dioxide. A 140 mesh Silica Flour (about 2 percent retained on a 140 mesh (106 microns) sieve) has a particle size distribution of 100 percent by weight less than 150μm, with a median diameter (50 percent by weight) of 20 ±5 μm. Particle size distribution must also be considered. A particle size distribution of 100 percent by weight less than 150 μm, with a median diameter (50 percent by weight) of 20 ±5 μm has been used in prior testing and is recommended."

3. For blowing sand tests MIL-STD-810G states that "the recommended particle size distribution for the large particle sand test is from 150 μm to 850 μm, with a mean of 90 ±5 percent by weight smaller than 600 μm and larger than or equal to 150 μm, and at least 5 percent by weight 600 μm and larger. When materiel is designed for use in a region that is known to have an unusual or special sand requirement, analyze a sample of such sand to determine the distribution of the material used in the test." Thus sand particle size distribution can be tailored to the deployment area.

4. White Sands Missile Range (WSMR) has utilized several different mixtures over the last 10 years. Table A-1 and Figure A-1 provides some data on the sands used in test. Some mixtures have been selected for their close approximation to the particle size distribution of Southwest Asia sands.

5. Table A-2 is a spreadsheet example used to calculate the sand/dust test parameters for two test configurations. The sand and dust feed rates are calculated by measuring the material quantity delivered over a unit time using the following formula:

$$\text{Rate} = (\text{Concentration}) \times (\text{Area}) \times (\text{Velocity})$$

where:

Rate = mass of sand introduced into the test chamber per set time interval

Concentration = sand concentration required by the test plan

Area = cross-sectional area of the wind stream at the test item location.

Velocity = average velocity of air at the test item location

Table A-1. Representative Sand and Dust Particle Size Distributions

Sieve Size	Particle Size (μm)	MIL-STD-810E Sand	Featherlite Play Ground Sand [1] 1997	Featherlite Play Ground Sand[1] 2001	MIL-STD-810E Dust	Silica Flour	Saudi Arabian Sand	WSMR East Center-30 Sand[2]	Sand with Dust Mix 2008
20	850	1.0%	11.3%	9.6%				0.4%	20.4%
30	600	1.7%	9.1%	5.9%				2.2%	11.0%
40	425	14.8%	22.1%	17.6%				13.4%	17.4%
50	300	37.0%	31.3%	25.7%				21.1%	15.5%
70	212	28.6%	18.1%	26.4%				27.1%	9.9%
100	150	12.7%	5.9%	12.5%	0.0%	19.7%	60.1%	16.8%	5.0%
<100	>150	5.2%	2.2%	2.4%					
140	106				2.0%	54.5%	11.2%	11.4%	7.1%
200	75				8.0%	11.6%		5.3%	8.7%
325	45				15.0%	7.2%	10.0%	2.1%	4.1%
<325					75.0%	7.0%	18.7%	0.3%	0.7%
		101.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%

[1] Featherlite is a local materials producer in the WSMR region. Note: the particle size distribution changes slightly from year to year (and probably bag to bag)
[2] East Center-30 is a test site location at WSMR north of the White Sands National Monument.

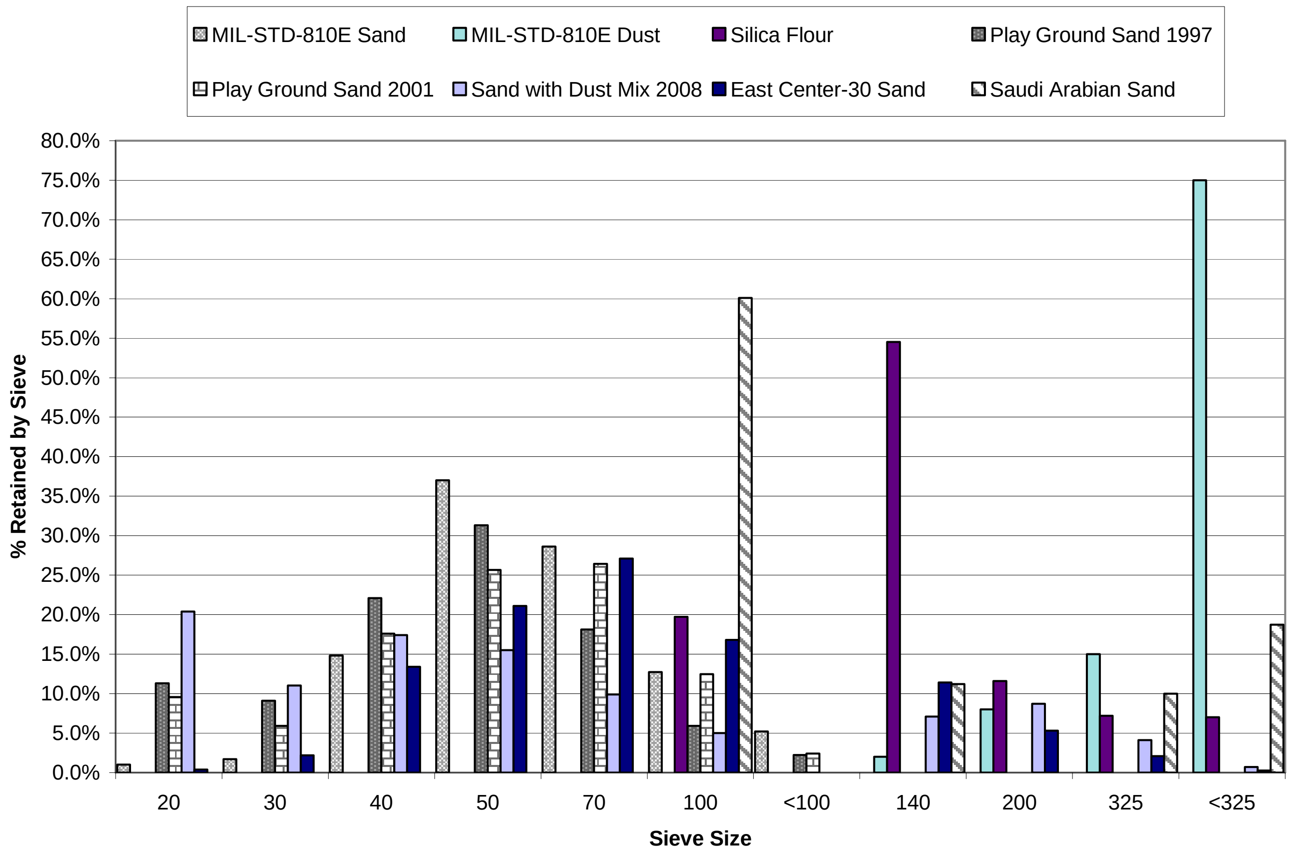

Figure A-1. Sand and Dust Particle Size Comparison, March 2008

Table A-2. Example Spreadsheet For Calculation of Sand/Dust Parameters

	Exposure Area 3m x 3m (10 ft x 10 ft)		Exposure Area 1.2m x 2.3m (4 ft x 7.5 ft)	
Sand/Dust Test Parameters	Sand	Dust	Sand	Dust
Concentration (g/m^3)	1.10	0.04	2.20	3.60
Velocity (mph)	40.2	40.2	40.2	40.2
Velocity (km/hr)	64.2	64.2	64.2	64.2
Velocity (ft/sec)	59.0	59.0	59.0	59.0
Velocity (m/s)	18.0	18.0	18.0	18.0
Wind Generator Area (ft^2)	100.0	100.0	30.0	30.0
Wind Generator Area (m^2)	9.3	9.3	2.8	2.8
Required Feed Rate (g/s)	183.9	6.7	110.3	180.6
Required Feed Rate (lbs/s)	0.405	0.015	0.243	0.398
Required Feed Rate (g/min)	11035.0	401.3	6621.0	10834.3
Required Feed Rate (lbs/min)	24.3	0.9	14.6	23.9
Total Material per Exposure (kg)	993.1	36.1	595.9	975.1
Total Material per Exposure (lbs)	2189.5	79.6	1313.7	2149.7
Total Test Material (kg), 4 sides[1]	3972.6	144.5	2383.6	3900.4
Total Test Material (lbs), 4 sides[1]	8758.0	318.5	5254.8	8598.7
ISO Fine (liters)		165.1		4457.6
ISO Course (gal)		32.2		868.6
Play Sand (# of 50 lb bags)	175.2		105.1	
Mix Proportions (lbs, kg, or grams)	27.50	1	0.61	1

[1] 90 minutes per side or 360 minutes of total exposure

APPENDIX B. SAND AND DUST CHARACTERIZATION

1. GENERAL.

This method characterizes the different particles within a soil/dust or powder-like sample by its size, roundness, hardness, and weight. The methods below may be applied to pre- and post-test verification studies of the sand/dust composition.

2. SPHERECITY AND ROUNDNESS.

Krumbein[4] defines particle sphericity as the cube root of the particle volume to circumscribed sphere volume ratio. Particle roundness “is a measure of the curvature of the corners and edges expressed as a ratio to the average curvature of the particle as a whole, independent of its form. For practical purposes the "average curvature" is expressed in terms of the inscribed circle drawn on a projection of the particle in a plane.” Figure B-1 is a visual chart used to determine the Krumbein number.

3. HARDNESS.

The Mohs hardness scale was introduced in 1822 and is still used as a classification for some minerals. The Mohs hardness value is an arbitrary scale. It simply consists of 10 minerals arranged in order from 1 to 10. Diamond is rated the highest and is indexed as 10. Talc is the

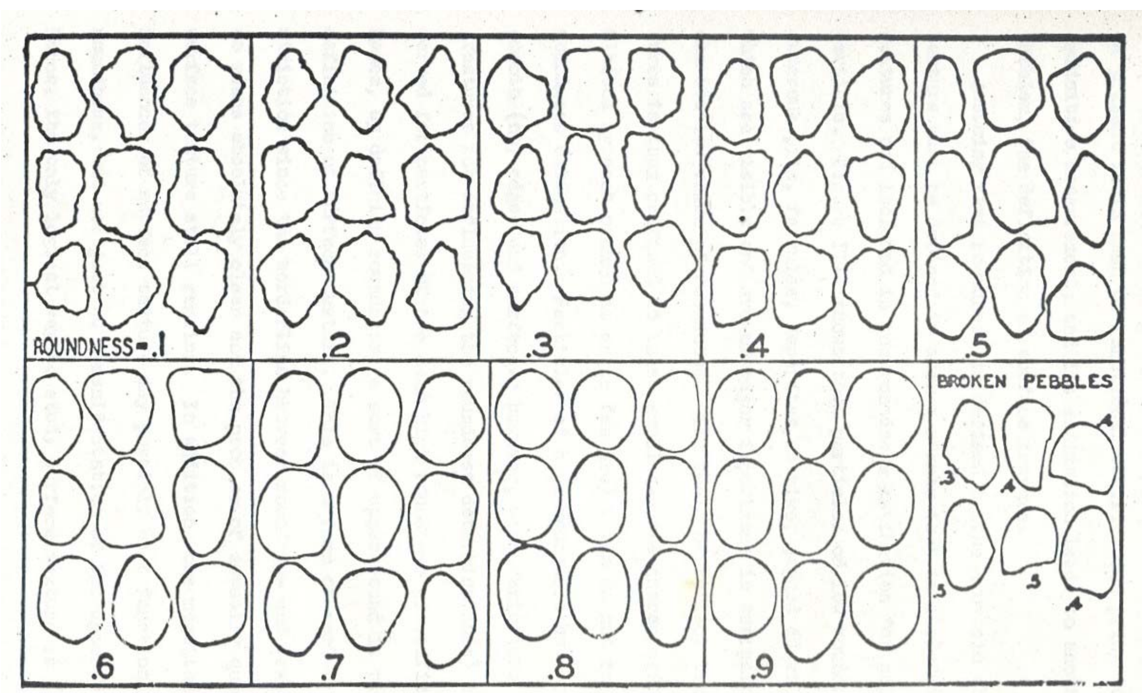

Figure B-1. Roundness Chart For 16-32 mm Pebbles (Krumbein 1941)

softest with an index number of 1. Each mineral in the scale will scratch those with a lower number. Copper would be in the 2 to 3 range, iron would be between 3 to 4 and hardened steels are in the 7 to 8 range. This is a scratch hardness scale. The scale is provided in Table B-1.

Table B-1. Mohs Hardness Scale

Hardness Scale	**Mineral**
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

4. MESH SIZE DEFINITION.

Mesh size refers to a specific particulate matter size range which can pass through a specific size sieve as show in Table B-2.

Table B-2. Mesh Sizes

Sieve #	**Mesh #**	**Microns**[1]
1	20	850
2	30	600
3	40	425
4	50	300
5	70	212
6	100	150
7	140	106
8	200	75
9	325	45
1000 microns = 1mm		

[1] Maximum passable particle size

5 HEALTH & SAFETY WARNINGS.

Wear appropriate protective eyewear, mask, and clothing. Breathing dust particles can be hazardous to one's health. Ensure adequate ventilation is available or set up the shaker equipment in an exhaust hood.

6. EQUIPMENT & MATERIALS.

a. Meinzer II sieve shaker or equivalent.

b. Analytical balance sensitive to 0.001 grams (g) and capable of weighing up to 1000 g.

c. US standard 8 inch sieves, mesh #s: 20, 30, 40, 50, 70, 100, 140, 200, and 325.

d. Temperature oven capable of sustaining a temperature of 110 °C for two hours.

e. Beakers, 250 and 500 ml, depending upon the amounts of sample to be analyzed.

f. Spatulas, different sizes for handling dust samples.

g. Brush and a compressed air source for cleaning purposes.

h. Desiccator.

i. Ziploc plastic bags, 35 x 40 cm (14 x 16 inches).

j. Other particle sizing/characterization instruments may be used if available and performance is proven.

7. SAMPLE PREPARATION.

7.1 Sample Collection.

a. All sample containers must be weighed before and after sample collection due to potentially different container weight values. The number of samples and containers will depend on the project requirements.

b. If filters are used to collect samples, each must be weighed and its ID, type, and lot number recorded before sample collection. Once the sample is collected, the sample collector will place each filter inside a pre-weighed plastic bag; the sampler needs to exercise caution to avoid sample loss during the transfer.

c. Prior to the characterization, before any sample is removed from any filter, filters will be weighed again inside their plastic bag.

7.2 Moisture Removal.

a. A representative sample will be placed in a labeled beaker. The amount of sample used will depend on the total amount of sample collected and its physical properties.

b. The samples will be placed in an oven and baked at 110 ˚C for two hours to remove any moisture. Desiccant material should be inside the oven to prevent the samples from absorbing moisture during the cool down period.

c. Let the samples cool down inside the oven and once at room temperature place it in a Ziploc plastic bag to avoid contact with moisture. If possible, store samples in a desiccator until the particle size distribution analysis can be performed.

8. PROCEDURE.

a. Before every analysis, each sieve must be cleaned with a brush and/or compressed air and weighed.

b. The sieves are nested one on top of the other in order of decreasing mesh size, with the largest mesh number on top and the collection pan on bottom. All sieves are used unless otherwise specified.

c. Place the weighed sample in the top (first) sieve.

d. Activate the Meinzer II Sieve Shaker or equivalent device and shake the sieves for thirty minutes (see Figure B-2). NOTE: Samples containing very small particles (dust) have the tendency to remain in the sieves if the shaking process is too strong. Static electricity keeps the tiny particles attached to the walls of the sieves and to other bigger particles. To overcome this problem, it is helpful to use a micro-pulse shaker such as the Meinzer II Sieve Shaker. Be careful not to let small particles escape from the sieve setup during the shaking process. If necessary, the sieves can be sealed with adhesive tape. Consider the weight added by the adhesive material to the sieves for calculation purposes.

e. After the shaking process is complete, weigh each sieve to determine the weight of the retained sample.

9. DATA ACQUISITION, CALCULATION & REDUCTION.

a. Record the weight of each clean sieve (without sample) before the test.

Figure B-2. Sieve Shaker Set-up

b. Record the weight of each sieve after the test including the weight of the sample retained inside the sieve.

c. Determine the weight of the sample retained inside each sieve using the following equations.

C = Initial sample weight.

S_n = Sieve weight. The subscript ‘n’ represents the sieve number, and ‘i’ or ‘f’ will indicate the initial or final weight of the sieve.

W_n = Indicates the sample weight retained in the ‘n’ sieve

$$W_n = S_{nf} - S_{ni}$$

(1) The sample weight percentage ($W_{\%n}$) retained inside the sieve.

$$W_{\%n} = \frac{(W_n)x(100)}{C}$$

(2) The sample weight passing (W_{P1} or W_{Pn}) through the ‘n’ sieve.

$$W_{P1} = C - W_1$$
$$W_{Pn} = C - (W_1 + W_2 + ...W_n)$$

(3) The sample weight percentage passing ($W_{P\%n}$)through the ‘n’ sieve.

$$W_{P\%n} = \frac{(W_{Pn})x(100)}{C}$$

d. Unless otherwise specified by the customer, the weight of each empty sieve before the test, the weight of each sieve after the test including the weight of the sample retained inside, the weight of the sample retained inside the sieve, the sample weight percentage retained inside the sieve, the sample weight passing through each sieve, and the sample weight percentage passing through each sieve will be reported. Each sample will be reported individually. Figures B-3 and B-4 show a suggested format to record and plot data. Figure B-3 represents the sample weight percentage retained in each sieve corresponding to a specific size range in microns. The last column shows the sample weight percentage that went through all the sieves and was collected at the bottom pan.

Date: 23 December 2008 Project: Sand and Dust Example

Sample ID: 5 - Initial (hopper) Analyst: ______________

Initial Sample Weight: 218.5 g

Sieve #	Mesh #	Sieve Weight (g)		Sample Retained (g)	Sample Retained %	Sample Through (g)	Sample Through %
		Before	After				
1	20	608.5	653.1	44.6	20.4	173.9	79.6
2	30	579.3	603.4	24.1	11.0	149.8	68.6
3	40	531.5	569.5	38.0	17.4	111.8	51.2
4	50	564.2	598.0	33.8	15.5	78.0	35.7
5	70	503.9	525.4	21.5	9.9	56.5	25.8
6	100	488.2	499.2	11.0	5.0	45.5	20.8
7	140	486.7	502.3	15.6	7.1	29.9	13.7
8	200	480.0	499.0	19.0	8.7	10.9	5.0
9	325	462.6	471.6	9.0	4.1	1.9	0.9
Bottom Pan		501.3	502.8	1.6	0.7	--	--
Sample Recovered: 218.2 g				Sample Recovered %: 99.9			

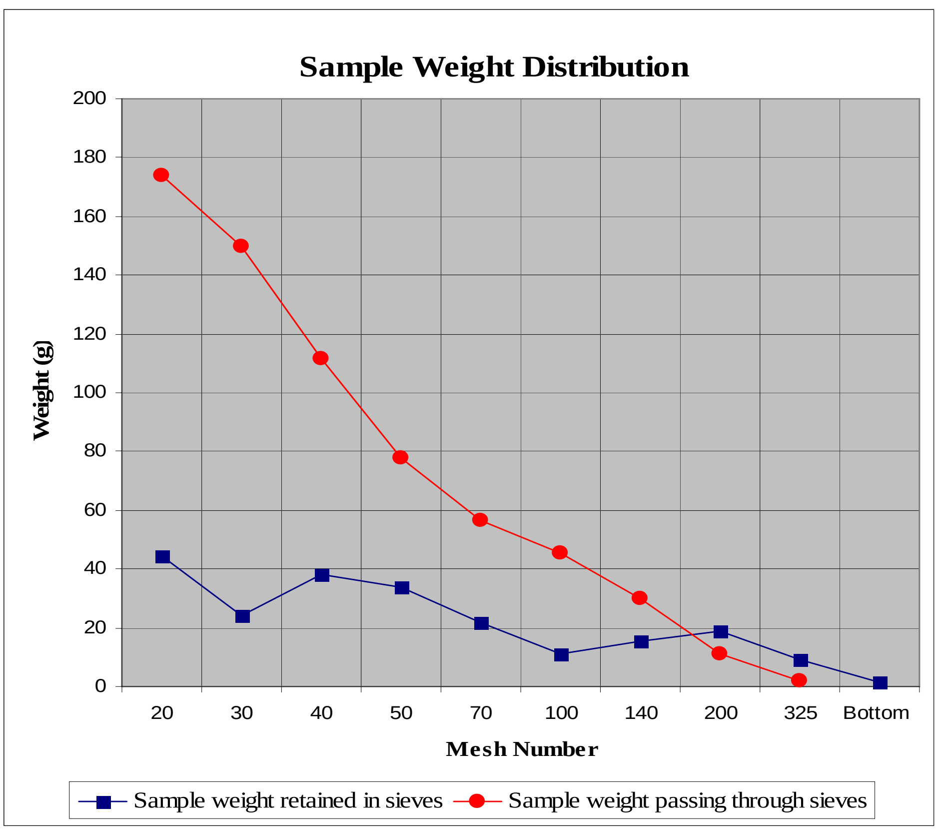

Figure B-3. Graphical Depiction of Sand Particle Distribution by Weight

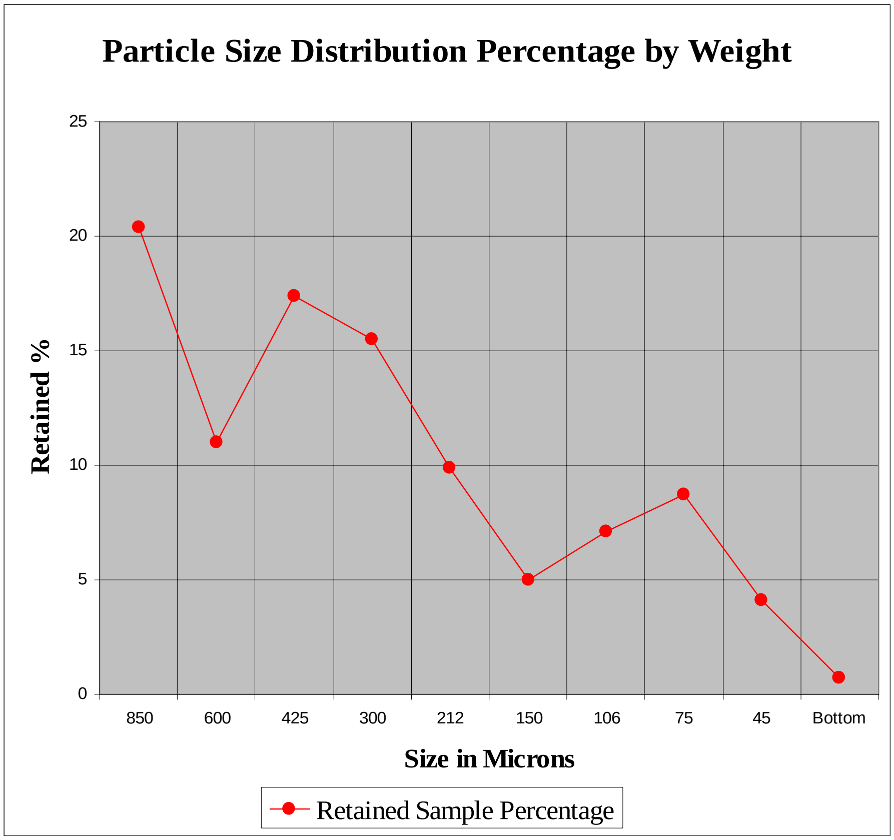

Figure B-4. Graphical Depiction of Particle Size Distribution by Percent

APPENDIX C. REFERENCES

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FOR INFORMATION ONLY

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c. USAAVLABS Technical Report 70-36, Mechanisms of Sand and Dust Erosion in Gas Turbine Engines", http://handle.dtic.mil/100.2/AD876584, August 1970

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the Technology Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road, Aberdeen Proving Ground, Maryland 21005-5055. Technical information may be obtained from the preparing activity: US Army White Sands Missile Range, TEDT-WSV, White Sands Missile Range, NM 88002-5178. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.